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TSU111, TSZ182 op amps & P-NUCLEO-IKA02A1

January 31st, 2023

ST Op Amps

Agenda

- Zero-drift technology
- TSZ181 and TSU111 CMOS op amps
- P-NUCLEO-IKA02A1: STM32 Nucleo electrochemical toxic gas sensor expansion board with CO sensor

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ST’s family of zero-drift amplifiers
Technology and device parameters

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Our family of chopper amplifiers

Best in precision, large input and output operating range

TSZ121	TSZ122	TSZ124	TSZ182	TSZ181	TSU111	TSU112	TSU114

1000 factor gain!

Op amp type	Standard commodity	Precision	Chopper TSZ
Input offset voltage	5 mV	400 µV	5 µV
Offset drift	30 µV/°C	1 µV/°C	30 nV/°C
1/f noise	High	Medium	No
Input and output range	Limited	Full range	

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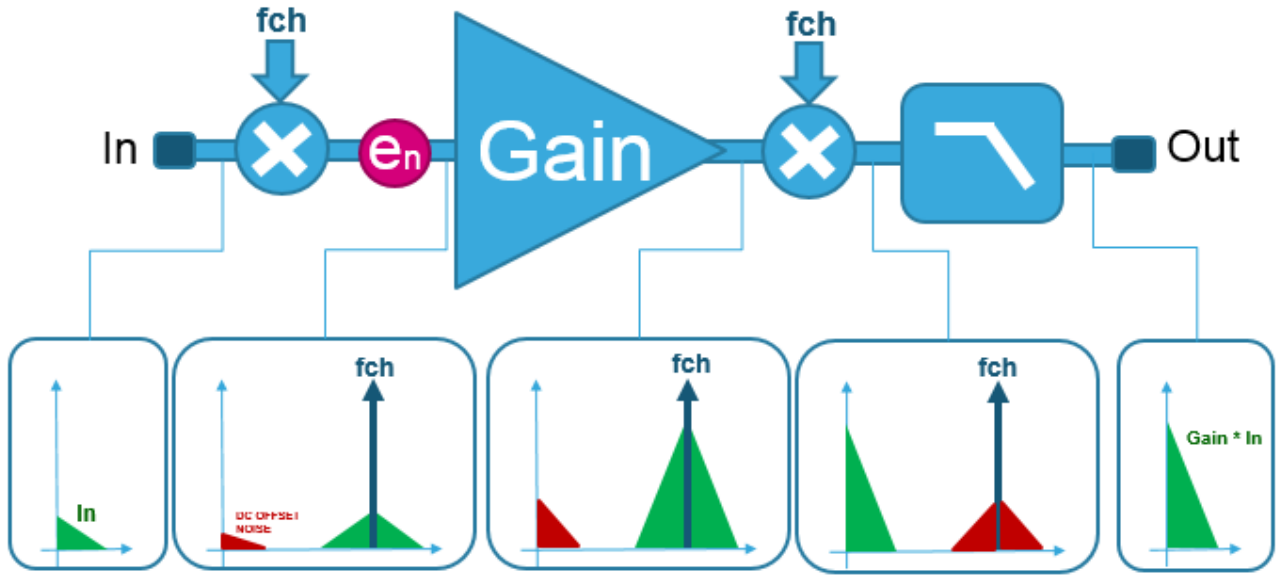
Zero-drift amplifiers

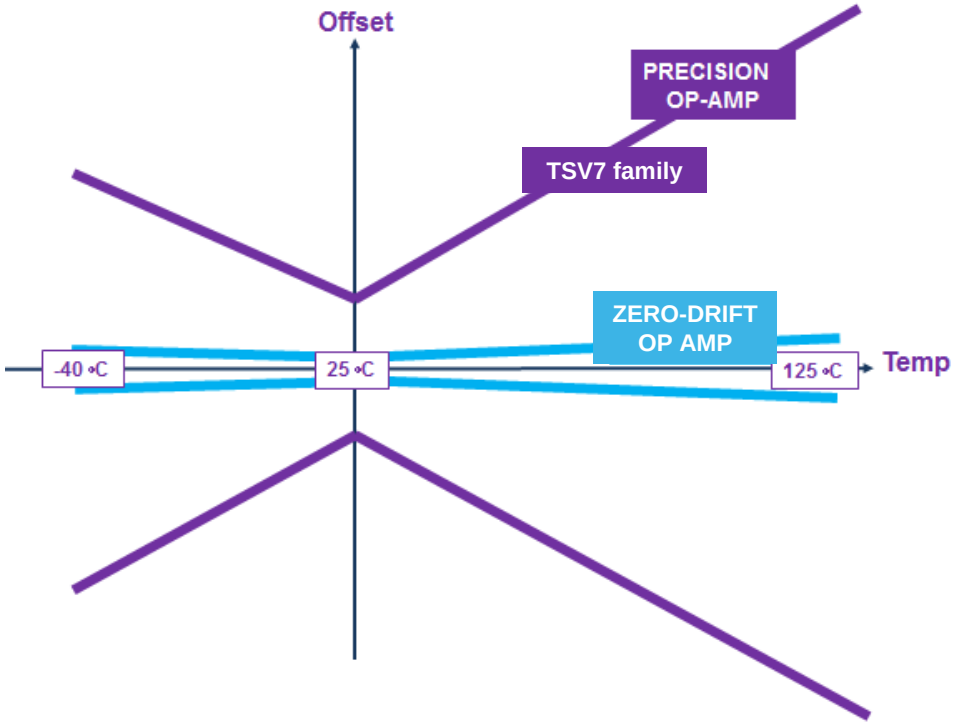
Frequency domain explanation



The **input signal** faces one **modulation** and one **demodulation.** The DC **errors** (offset and (1/f) noise) face one **demodulation only,** resulting in permanent amplifier **imperfection cancellation.**

Zero-drift amplifiers

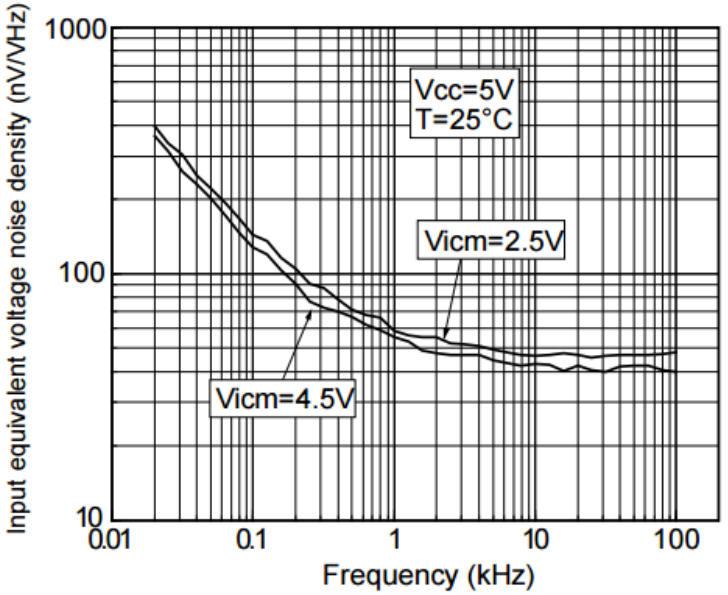
Zero-drift op amps really don’t drift

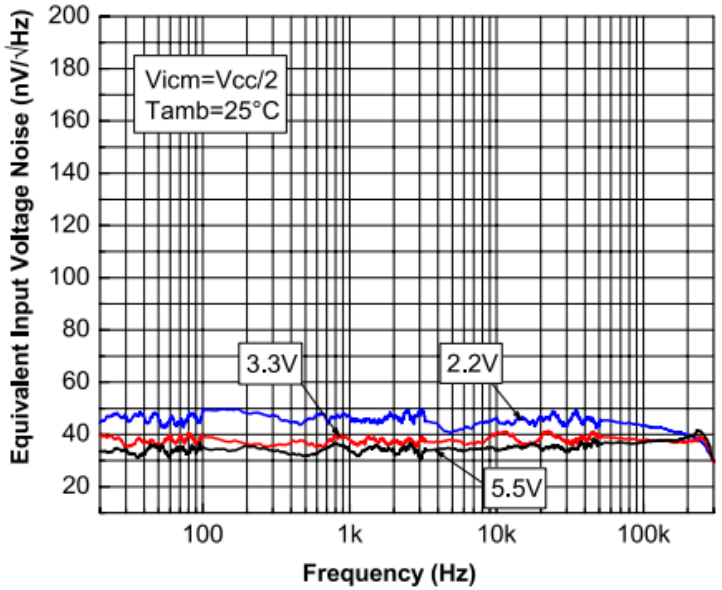


Input offset voltage imperfection changes with temperature, however as a DC error it is canceled.

Zero-drift amplifiers

1/f noise has disappeared





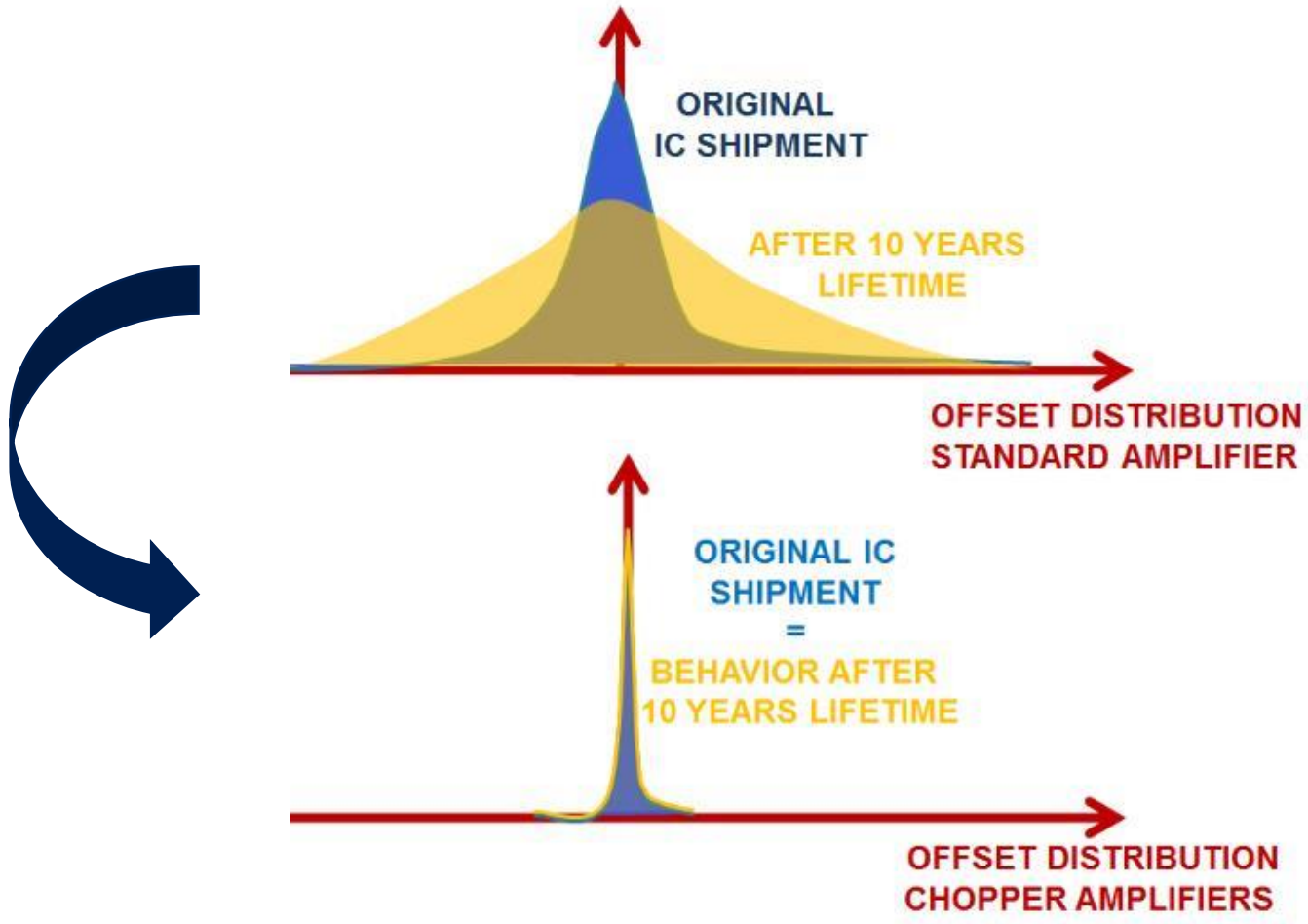
TSV63x
general purpose CMOS op amp

TSZ18x
Chopper CMOS op amp

1/f noise increases with lower frequencies making standard CMOS op amps less precise in very slow applications. This noise disappears in chopper architecture thanks to modulation.

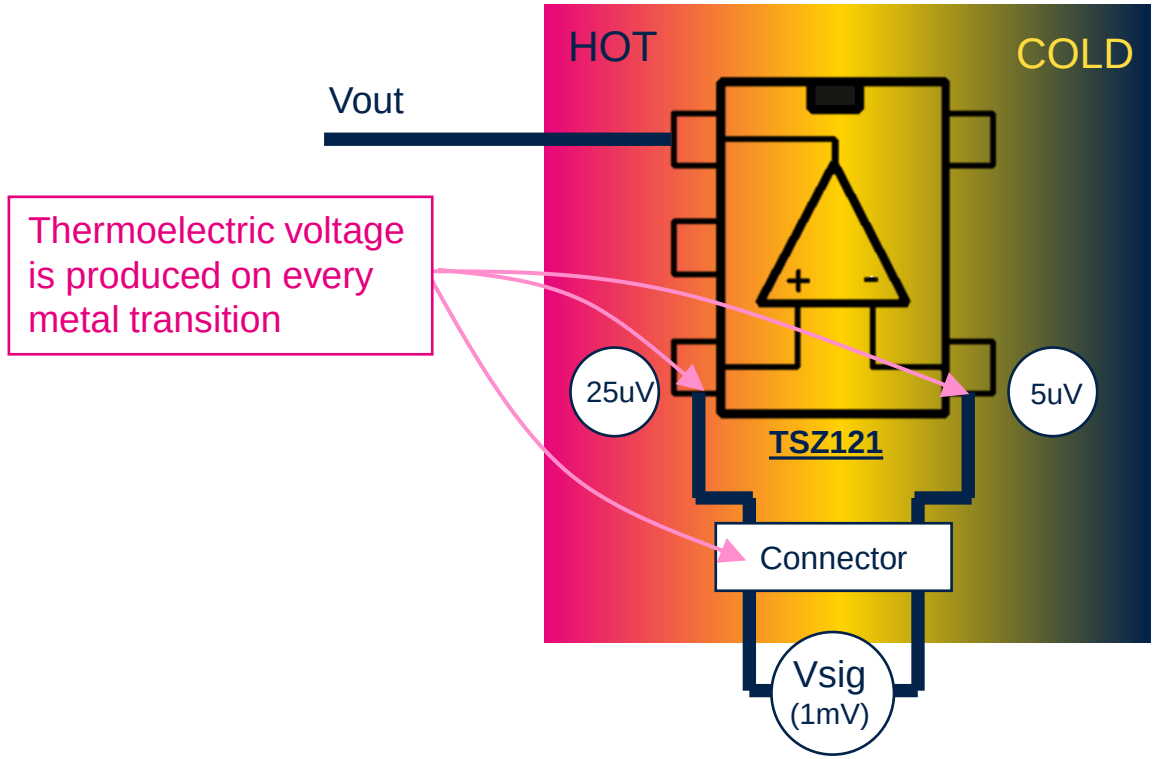
Zero-drift amplifiers

Stays young forever



Zero-drift amplifiers

Heat can destroy your precision



Every **metal transition produces tiny voltage**. If there is some **temperature gradient** on the device the voltages differ and the op amp **cannot distinguish** this from real signal.

Temperature	Input signal	Impact of Vio	Impact of Vterm	Error
Stabilized (no difference)	1 mV	5 µV	0 µV	0.5%
Temp gradient (big difference)	1 mV	5 µV	20 µV	2.5%

Recently featured zero-drift amplifiers: TSU111 and TSZ181

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TSZ181, TSZ182, TSZ181H, TSZ182H, TSZ182H1

Very high accuracy for very high temperature

- Very high accuracy and stability:
  - 25 µV max. at 25°C
  - 35 µV -40°C to 125°C
  - 44 µV max. at 150°C
  - 65 µV max. at 175°C
- Gain bandwidth product: 3 MHz
- Rail-to-rail input and output
- Low supply voltage: 2.2–5.5 V
- High slew rate: 4.7 V/µs

Accuracy virtually unaffected by temperature change

TSZ182H1YDT
SO8

TSZ181HYLT
SOT23-5

TSZ181HY, TSZ182HY
High temperature operating **up to 150°C**

TSZ182H1Y High temperature operating **up to 175°C**

Exhaust & emission control

Engine Control Unit (ECU)

Brake system

Gearbox system

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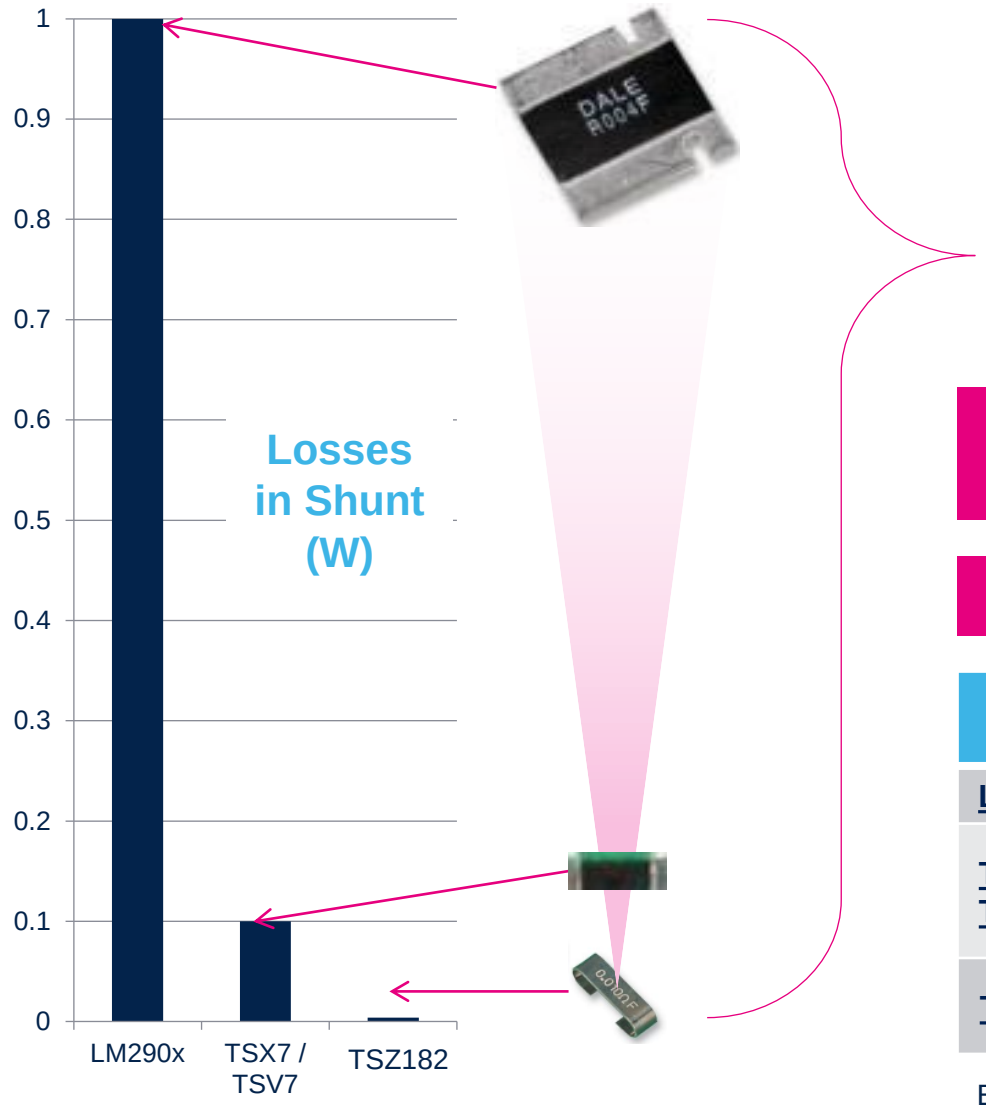
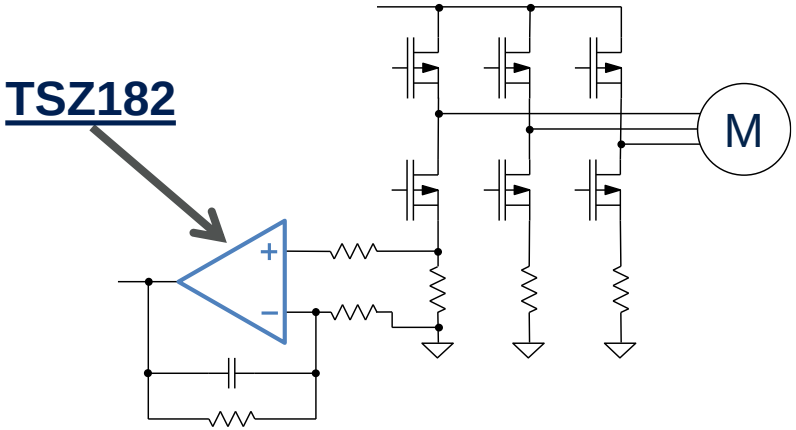
BLDC motor control





High precision op amp smaller shunt → minimize losses

High slew rate → track PWM

Part	Op amp	Vio max (mV)	Shunt (mΩ)	Losses (W)
LM290x	Standard	2	40	1
TSV7xx TSX7xx	High precision 5 V CMOS 16 V CMOS	0.2	4	0.1
TSZ18x	Ultraprecision 5 V zero-drift	0.025	0.5	0.0125

Example: low-side current sensing. Imax = 5A, precision 1%

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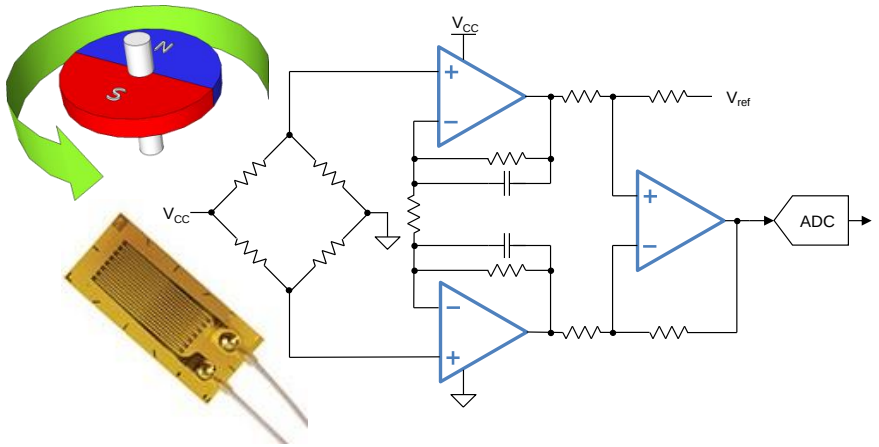
High-speed instrumentation amplifier

High speed signal conditioning from sensors in Wheatstone bridge

- AMR magnetic sensors → dynamic magnetic field around motor, wire.
- Strain gauges → dynamic mechanical constrains.



High precision op amp
Better accuracy → more bits

High GBW→ dynamic signals

	Vio max	Max offset at ADC with gain of 100 (Vio impact 202x)	Equivalent Effective ADC bits
TSZ182	25 µV	5.05 mV	~10 bits
TS507	100 µV	20.2 mV	~8 bits
TS512A	500 µV	101 mV	~6 bits
TS512	2.5 mV	505 mV	~3 bits

Example: 12-bit ADC in STM32 with 3.3 Vref → LSB = 805 µV

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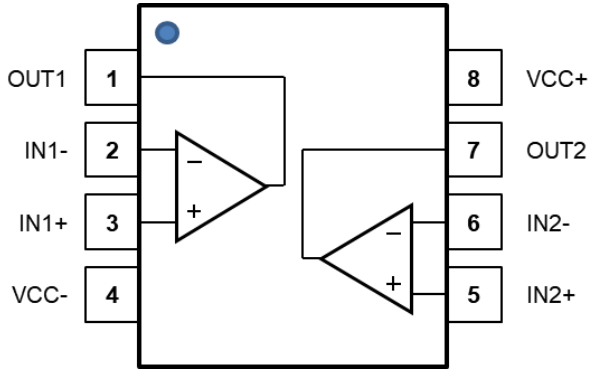
TSU111, TSU112, TSU114

Nano-power precision amplifier



Benefits

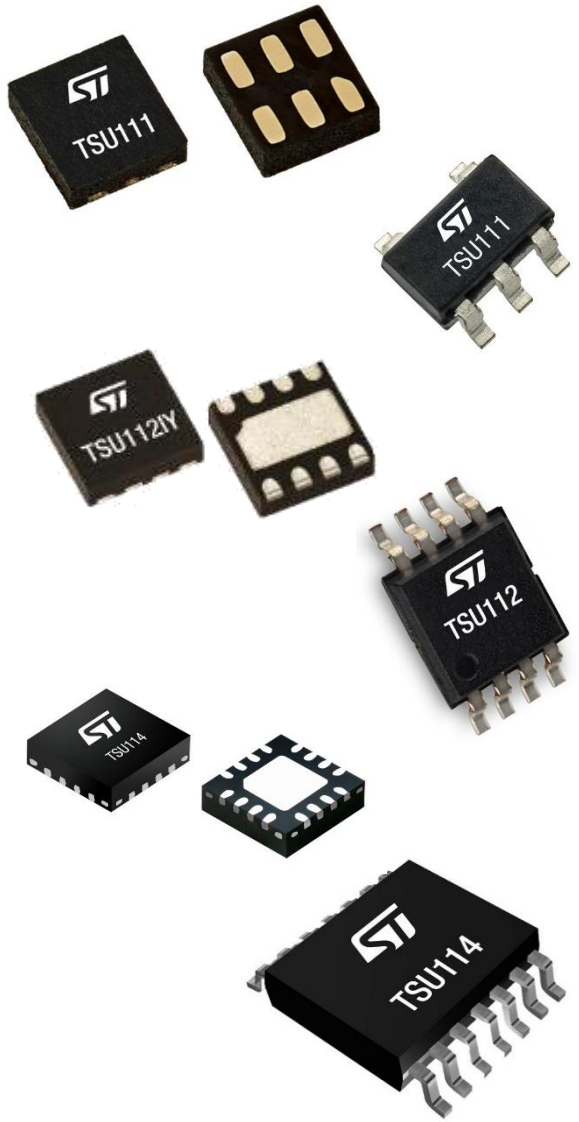
- Suitable for always on applications
- High accuracy without calibration
- Running more than 25 years on CR2032 coin cell battery

Key Features

- Sub-microampere current consumption:
  - Icc = 900 nA typ. at 25°C
- Low offset voltage:
  - 150 µV max. at 25°C
  - 235 µV max. -40 to 125°C
- Low noise over 0.1 to 10 Hz: 3.6 µVpp
- Low supply voltage: 1.5 V to 5.5 V
- Gain bandwidth product: 11.5 kHz typ

Target applications

- Car access
- Alarm and anti-theft
- Telematic boxes
- Surrounding monitoring



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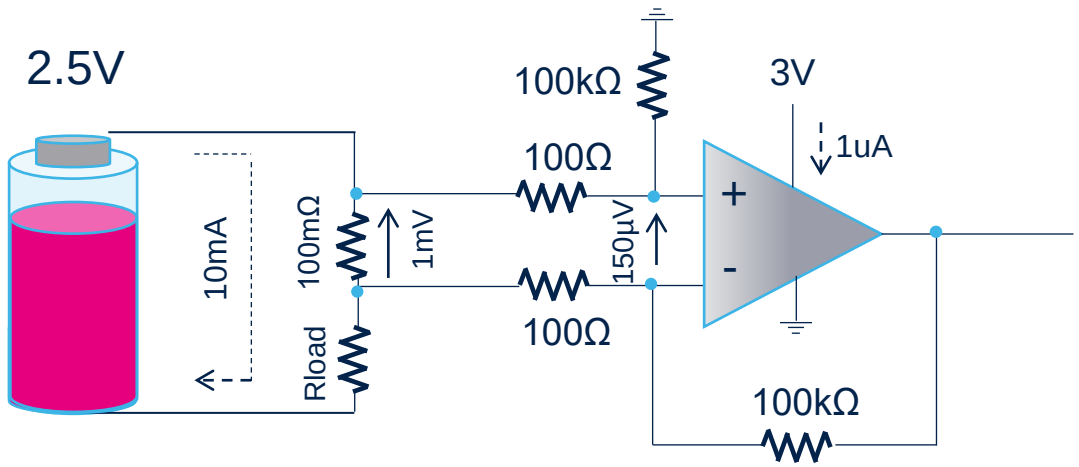
Current sensing in battery-powered applications



	Vio max	Supply current	Impact on application
TSU111	150 µV	1 µA	0.01%
TSV711	200 µV	14 µA	0.14%
TS507	100 µV	1 mA	10%

Example : Op amps with similar V_{IO} selected

Ideal for wearables

Battery current sensing
for SOC estimate

High precision op amp
Better accuracy → more bits

Low power consumption → longer battery lifetime

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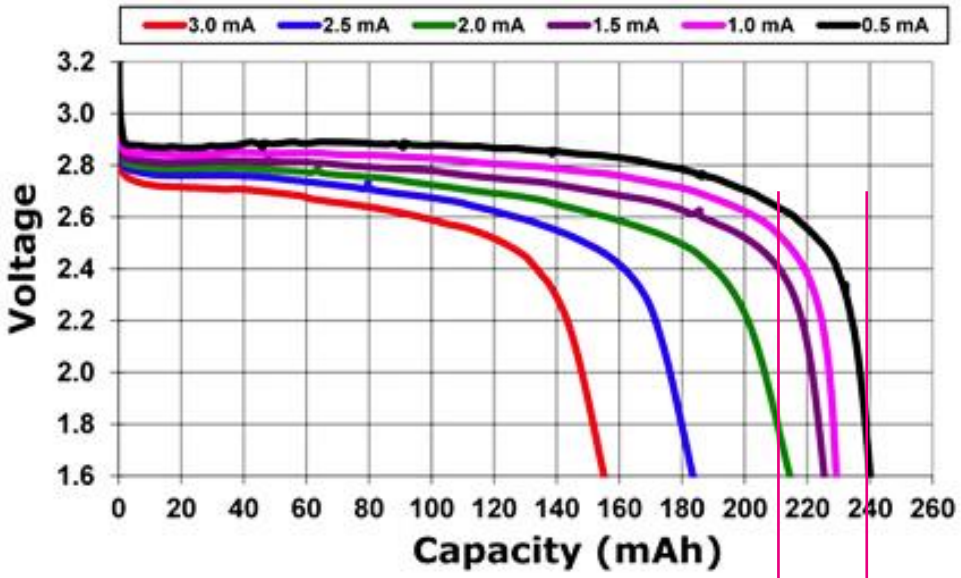
Works from very low voltage

Typical CR2032 discharge characteristic



End of life: **2.7V 1.5V**

Most op amps can work down to 2.7 V or 2.5 V
TSU111 can work with 1.5 V → get all the power from the battery

>10% remains
@ 500 µA load

Note: Even in applications that consume 10 µA or less, this op amp can help extend battery lifetime by weeks or months.

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P-NUCLEO-IKA02A1

STM32 Nucleo electrochemical toxic gas sensor expansion board with CO sensor

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Electrochemical gas sensor expansion board

P-NUCLEO-IKA02A1 hardware description

- The P-NUCLEO-IKA02A1 is an electrochemical gas sensor evaluation board.
- It embeds several footprints to host different types of sensors and different target gases.
- The connectivity is assured thanks to Arduino UNO R3 connector and ST morpho connector layout.

Key products on board

TSU111

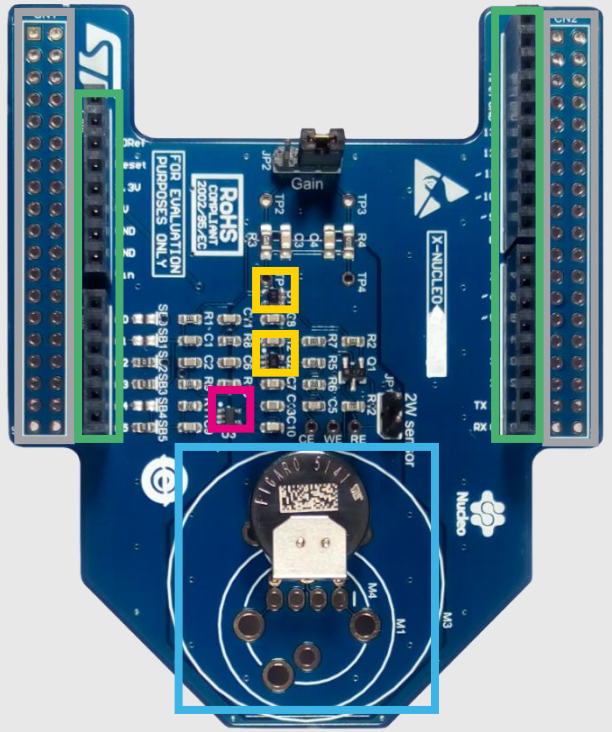
Nanopower (900 nA), high accuracy (150 µV) 5 V op amp.

STLM20

Ultra-low current 2.4 V precision analog temperature sensor.

Gas sensor

4 different footprints for various electrochemical gas sensors (PCD 13.5 mm, PCD 17 mm, miniature, TGS5141).



Gas sensor footprints

STLM20

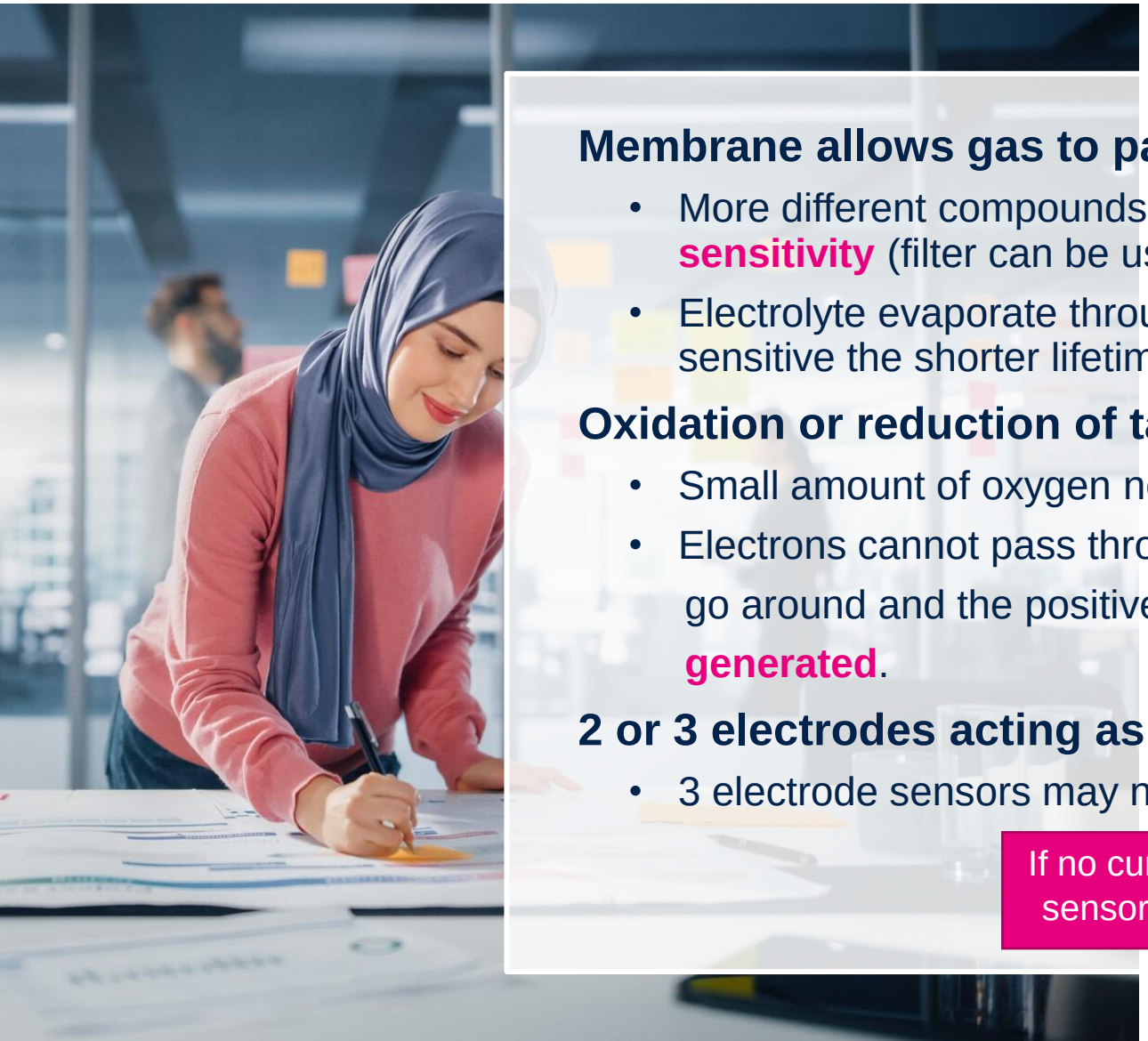
TSU111

ST morpho connector**

Arduino UNO R3 connector

Latest info available at www.st.com
P-NUCLEO-IKA02A1

Working principle of electrochemical sensors

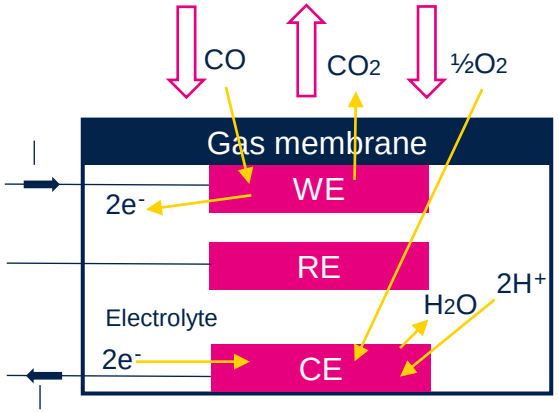


Membrane allows gas to pass through and react with electrode

- More different compounds can pass through membrane and causes **cross sensitivity** (filter can be used).
- Electrolyte evaporate through membrane – **limited lifetime** (the more sensitive the shorter lifetime).

Oxidation or reduction of target gas

- Small amount of oxygen needed.
- Electrons cannot pass through electrolyte so it must go around and the positive or negative **current is generated**.



2 or 3 electrodes acting as a catalyst

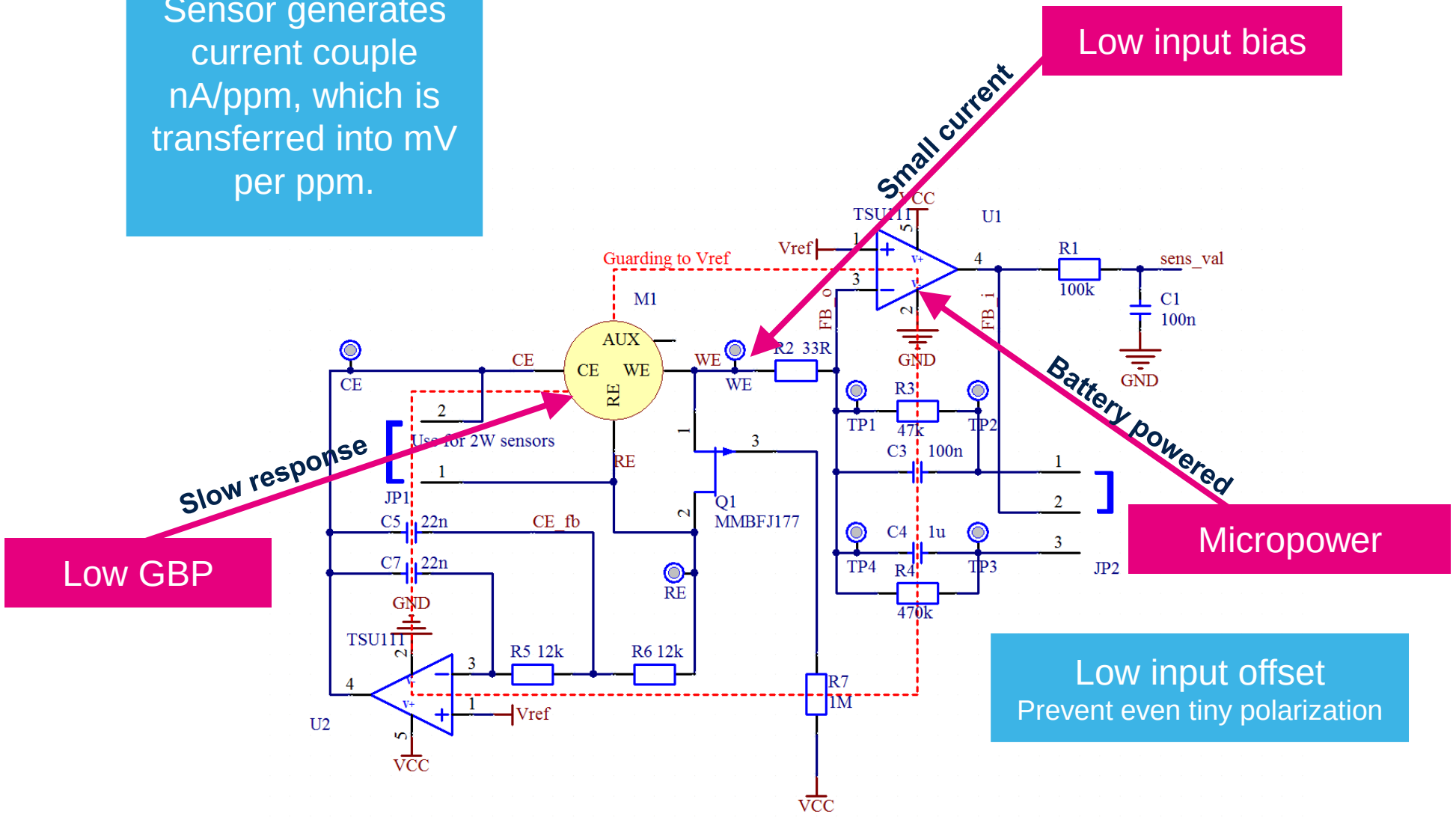
- 3 electrode sensors may need **bias voltage** to be applied.

If no current can flow sensor will polarize

CO, CO_2, O_2, O_3, NO_x, H_2S, H_2, Cl_2, ClO_2, C_xH_x, NH_3, SO_2

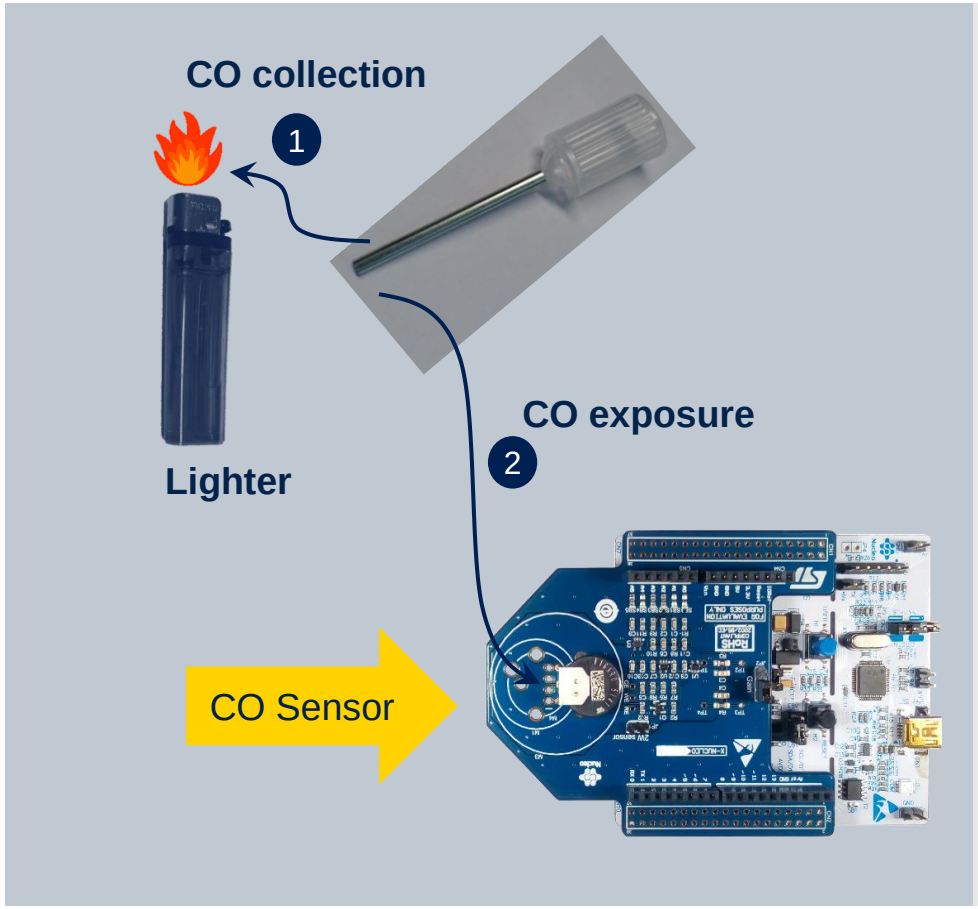
P-NUCLEO-IKA02A1 application schematic

Sensor generates current couple nA/ppm, which is transferred into mV per ppm.

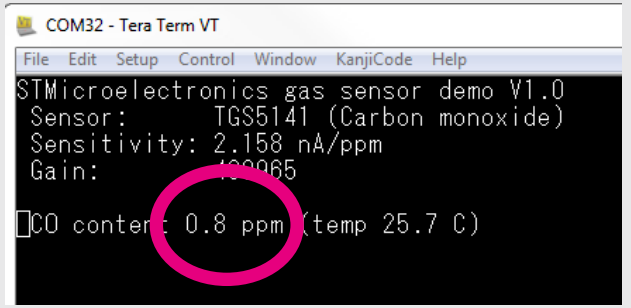


Low input offset
Prevent even tiny polarization

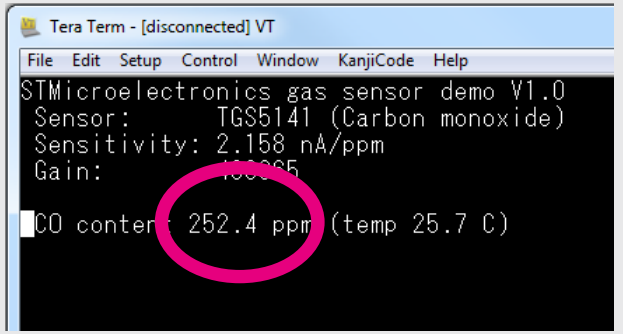
X-CUBE-IKA02A1 example using serial line monitor



No CO detected



CO detected – ppm value



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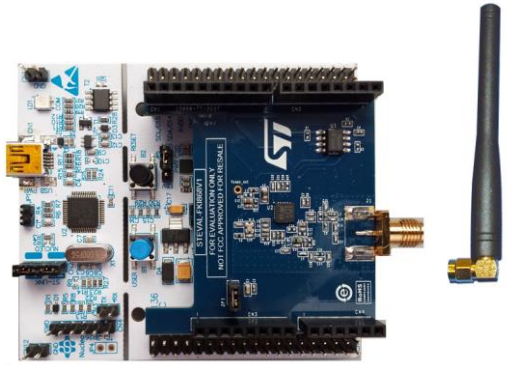
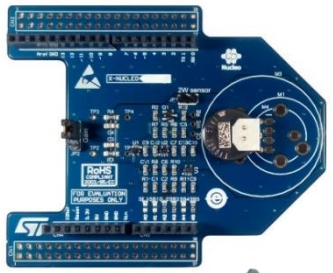
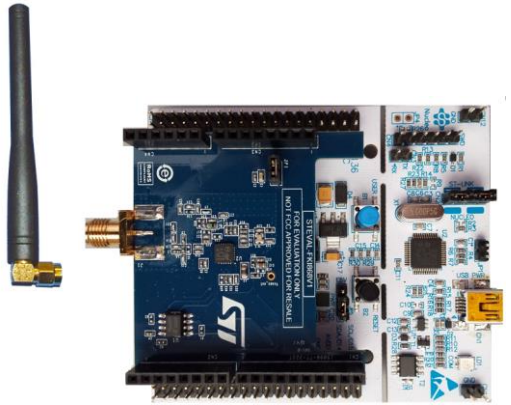
Wireless home carbon monoxide detector demo



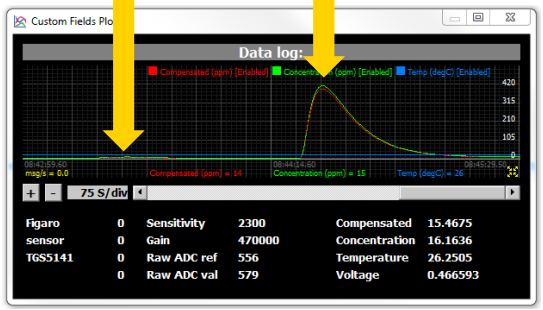


CO exposure



No CO detected

CO detected, ppm value



Unicleo-GUI

Our technology starts with You

Find out more at www.st.com

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